National Energy Savings (NES) and Shipments for Central Air Conditioners and Heat Pumps – Assumptions and Results

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Introduction

The National Energy Savings (NES) spreadsheet calculates both energy savings and national economic benefits. The national energy savings are the aggregate energy savings due to a new energy efficiency standard. In other words, it is the difference in the energy needed for the nation to air condition and/or heat before and after a higher efficiency standard goes into effect. To estimate the energy savings through the year 2030 due to revised standards, the energy consumption of central air conditioners or heat pumps under the base case is compared to the energy consumption of central air conditioners or heat pumps complying with the standard. In other words, the NES spreadsheet determines the energy used under a base case scenario (in the absence of a new efficiency standard) and under a standards case scenario. It then subtracts energy consumption in the standards case from that in the base case to determine energy savings.

The NES spreadsheet also calculates the net present value (NPV). The NPV is the discounted sum over future years of the operating cost savings in energy minus the increase in first cost of more efficient air conditioners or heat pumps. A net present benefit is a net present value that is positive.

This report presents results from the National Energy Savings (NES) and Shipments spreadsheet model. Shipments and NES are discussed together here because the forecasting of shipments is a required input into the NES model. There are three basic outputs from this analysis:

- Shipments are forecast for baseline (10 SEER) and five standard level conditions (11 through 15 SEER) for central air conditioners and heat pumps. These shipments are an input into the National Energy Savings model.
- The cumulative energy savings are determined for the nation through the year 2030.
- The net present value (NPV) is determined for each standard level.

Like the life-cycle cost and payback period analysis, two sets of results that include forecasts of shipments, energy savings, and NPV, are presented based on two different sets of manufacturer cost increases associated with increased efficiency. The two sets of manufacturer costs increases are identified as:

- **ARI** (Air-Conditioning & Refrigeration Institute) – ARI collected incremental cost estimates from individual manufacturers and calculated industry averages, and

- **Rev Eng** (Reverse Engineering) – cost estimates developed from current products through a reverse engineering analysis performed by Arthur D. Little, Inc. (ADL).

Unlike the LCC model, neither the National Energy Savings (NES) model or Shipments model use distributions of values as inputs. They do use the same basic data as the LCC model for the energy use and cost of the central air conditioning and heat pump equipment, but rather than input distributions, shipment weighted-average values are used instead.

Results Summary

Table 1 and Figures 1 through 4 depict the NES and national NPV results for central air conditioners and heat pumps based upon the ARI and reverse engineering cost data. For efficiency levels from 11 to 15 SEER, the table and figures show the cumulative NES and national NPV results over the time period of 2006 to 2030.

A detailed discussion of the inputs for the NES and NPV analysis follow the results summary. After the discussion of the input, more detailed NES and NPV results are presented.

Table 1 National Energy Savings and Net Present Value Results for Central Air Conditioners and Heat Pumps

Efficiency	Split Air Conditioners				Split Heat Pumps				Package Air Conditioners				Package Heat Pumps			
	ARI		Rev Eng		ARI		Rev Eng		ARI		Rev Eng		ARI		Rev Eng	
Efficiency	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**	**NES**	**NPV**
SEER	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*	*Quads*	*billion 98$*
Base Case [1]	24.33	-	24.32	-	27.76	-	27.75	-	3.83	-	3.83	-	4.66	-	4.66	-
11	0.68	-0.29	0.66	0.04	0.06	0.07	0.03	0.06	0.11	-0.21	-	-	0.01	0	-	-
12	2.46	-2.83	2.40	-0.16	1.19	-0.43	1.07	0.61	0.39	-0.36	0.38	0.21	0.2	-0.06	0.18	0.12
13	4.08	-7.66	3.94	-1.97	2.73	-1.27	2.68	-1.15	0.64	-1.96	0.62	-1.04	0.46	-0.51	-	-
14	5.49	-15.80	5.31	-8.54	4.05	-2.32	4.19	-3.85	0.86	-2.86	-	-	0.68	-0.52	-	-
15	6.65	-22.16	6.42	-12.27	5.50	-7.59	5.28	-5.64	1.04	-4.32	-	-	0.92	-1.17	-	-

[1] Values for Base Case are the cumulative national energy consmption from 2006 to 2030.

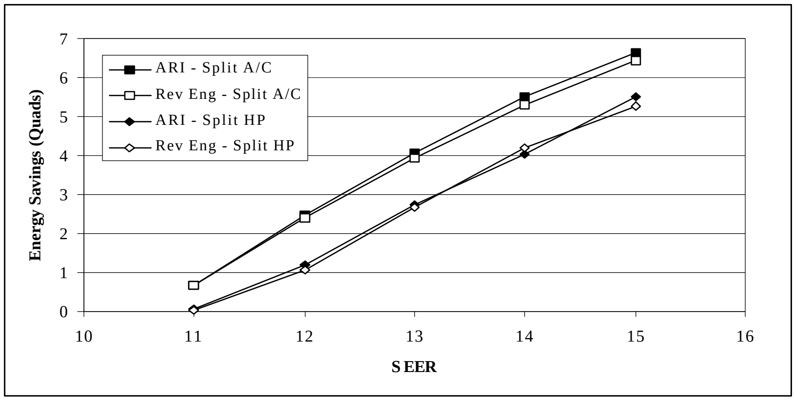

Figure 1 Split A/C and HP: Cumulative NES from 2006 to 2030

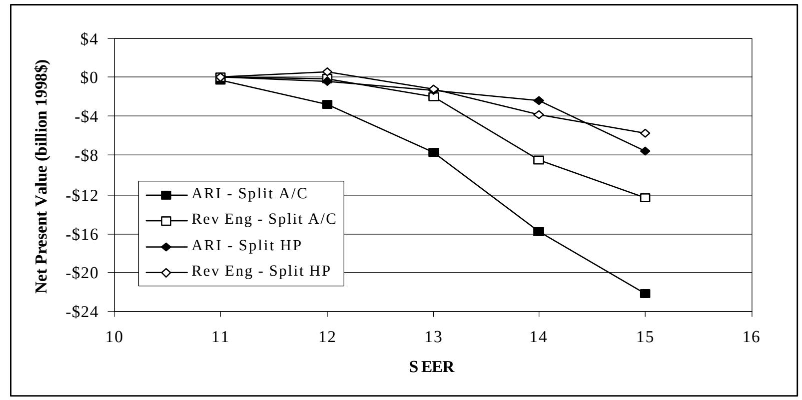

Figure 2 Split A/C and HP: Cumulative NPV from 2006 to 2030

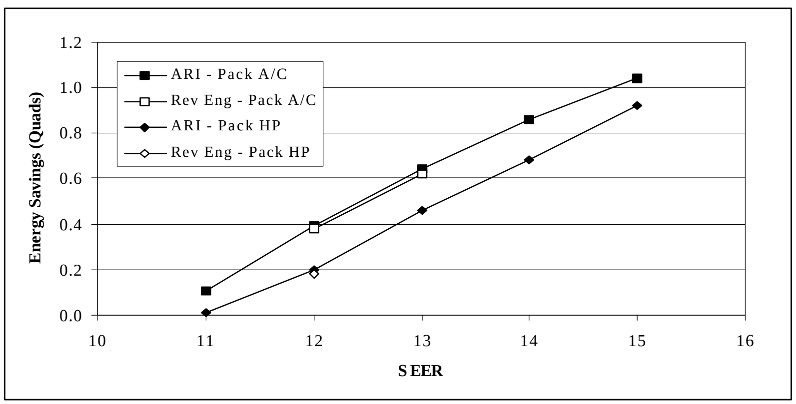

Figure 3 Package A/C and HP: Cumulative NES from 2006 to 2030

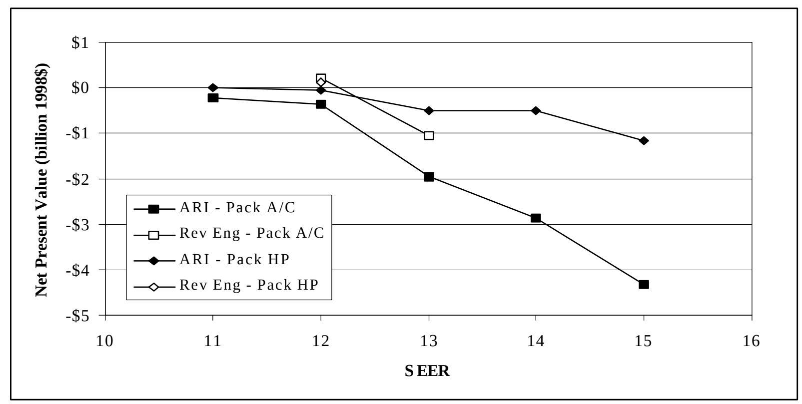

Figure 4 Pack. A/C and HP: Cumulative NPV from 2006 to 2030

National Energy Savings (NES) Model

The National Energy Savings (NES) model determines the national energy savings and net present value (NPV) associated with a particular standard level.

National annual energy savings are calculated as the difference between two projections: a base case (without new standards) and a standards case. Positive values of NES correspond to energy savings (i.e., energy consumption with standards is less than energy consumption in the base case).

The net present value is calculated from the projections of national expenditures for central air conditioners or heat pumps, including total installed consumer cost and operating expenses. Costs and savings are calculated as the difference between a new standards case and a base case without those new standards. Future costs and savings are discounted to the present with a discount factor. A discount factor is calculated from the discount rate and the number of years between the *present* (year to which the sum is being discounted) and the year in which the costs and savings occur. The net present value is the sum over time of the discounted net savings.

Table 2 summarizes the inputs and assumptions that are used in the NES model.

Table 2 NES Model Inputs and Assumptions

Parameter	Data Description
Shipments	Annual shipments from shipment model.
Total Installed Consumer Cost	***Average*** value for the baseline and each standard level. From life-cycle cost analysis.
Repair and Maintenance Costs	***Average*** values for the baseline and each standard level. From life-cycle cost analysis.
Historical Efficiencies	Shipment-weighted efficiency data (SEER) from the Air-Conditioning and Refrigeration Institute for the years 1976-1997.
Future Efficiency Trend	For the years 1998 to the assumed effective date of the new standard (2006), shipment-weighted efficiencies are assumed to remain constant at the shipment-weighed efficiency level in 1997. For years beyond the assumed effective date of the new standard, shipment-weighted efficiencies are assumed to equal the new standard level.
Unit Annual Energy Consumption	Based on the ***weighted-average*** annual energy consumption and efficiency from life-cycle cost analysis. To estimate the representative annual energy consumption of a central air conditioner or heat pump for any given year, the ratio of the RECS weighted-average efficiency to the efficiency level in that year is multiplied by the RECS weighted-average annual energy consumption.
Electricity Prices	Based on the ***weighted-average*** marginal electricity price determined from RECS93 in the life-cycle cost analysis.
Escalation of Electricity Prices	1999 EIA Annual Energy Outlook forecasts (to 2020) and extrapolation from 2020 to 2030.
Electricity Site-to-Source Conversion	Conversion varies yearly and is generated by EIA's NEMS-EPCA[1] program (a time series conversion factor; includes electric generation transmission and distribution losses).
Discount Rate	7% real.
Present Year	Future expenses are discounted to year 1998.

Shipment Model

Central air conditioner and heat pump shipment estimates are a necessary input for national energy savings calculations A sophisticated accounting model was used to determine shipment scenarios for each energy efficiency level. Central air conditioner and heat pump shipment projections account for:

[1]EIA approves use of the names NEMS (National Energy Modeling System) only to describe an AEO version of the model without any modification to code or data. Since, in this work, there will be some minor code modifications, DOE proposes use of the name NEMS-EPCA for the model as used here.

- Combined effects of price, operating cost, and household income on annual U.S. shipments.
- Market segments (e.g., new housing, replacement decisions, non-owners adding an air conditioner or heat pump).
- Decisions to repair rather than replace.
- Age categories of central air conditioners and heat pumps.

In the shipment forecast model, households are first divided into a Central Air-Conditioning (CAC) market and a Heat Pump (HP) market. Then both the CAC and HP markets are further divided into four different ownership categories, while consumer purchases of CAC and HP systems are divided into five different market segments. The four CAC and HP ownership categories are: (1) new housing, (2) existing housing with a regular CAC or HP, (3) housing without a CAC or HP, and (4) housing with an extended life CAC or HP. The population of CAC and HP units in each ownership category are referred to as the ***stock*** of CAC and HP units of that category.

Meanwhile the different types of CAC and HP purchases are divided into five separate market segments as follows:

- *Net New Housing Market*: When there is a net increase in the housing stock, the increase in the number of households will force the purchase of new CAC and HP systems.

- *Early (Discretionary) Replacement Market*: Even before a CAC or HP system breaks down, about 29% of CAC and HP owners replace the existing CAC and HP because they want an updated model, because of remodeling, or for other reasons.

- *Regular Replacement Market*: Most CAC and HP purchases result from the replacement of an existing CAC and HP that has broken down after the completion of its useful life.

- *Extra Repair Market*: Under conditions of high costs for new CAC and HP systems, a few consumers will rebuild or repair a broken down CAC and HP system (thus extending its lifetime) rather than purchasing a new CAC and HP system. Eventually, even extended life CAC and HP systems breakdown and are replaced.

- *Homes without a CAC or HP system*: A few households without a CAC or HP system will purchase a CAC or HP system and become new CAC or HP owners.

While there is some correlation between the different types of CAC and HP owners, the correspondence is not exact. The ownership categories reflect the type of CAC and HP that a consumer has, while the market segments reflect the reasons for purchasing a CAC or HP.

The CAC and HP shipments model keeps track of the population of each type of CAC and HP and CAC and HP purchase. Events and consumer decisions influence how the stock and supply of CAC and HP systems flow from one category to another. Decisions which are economically influenced are modeled with econometric equations. Figure 5 shows the detailed flow diagram for the CAC and HP shipment model.

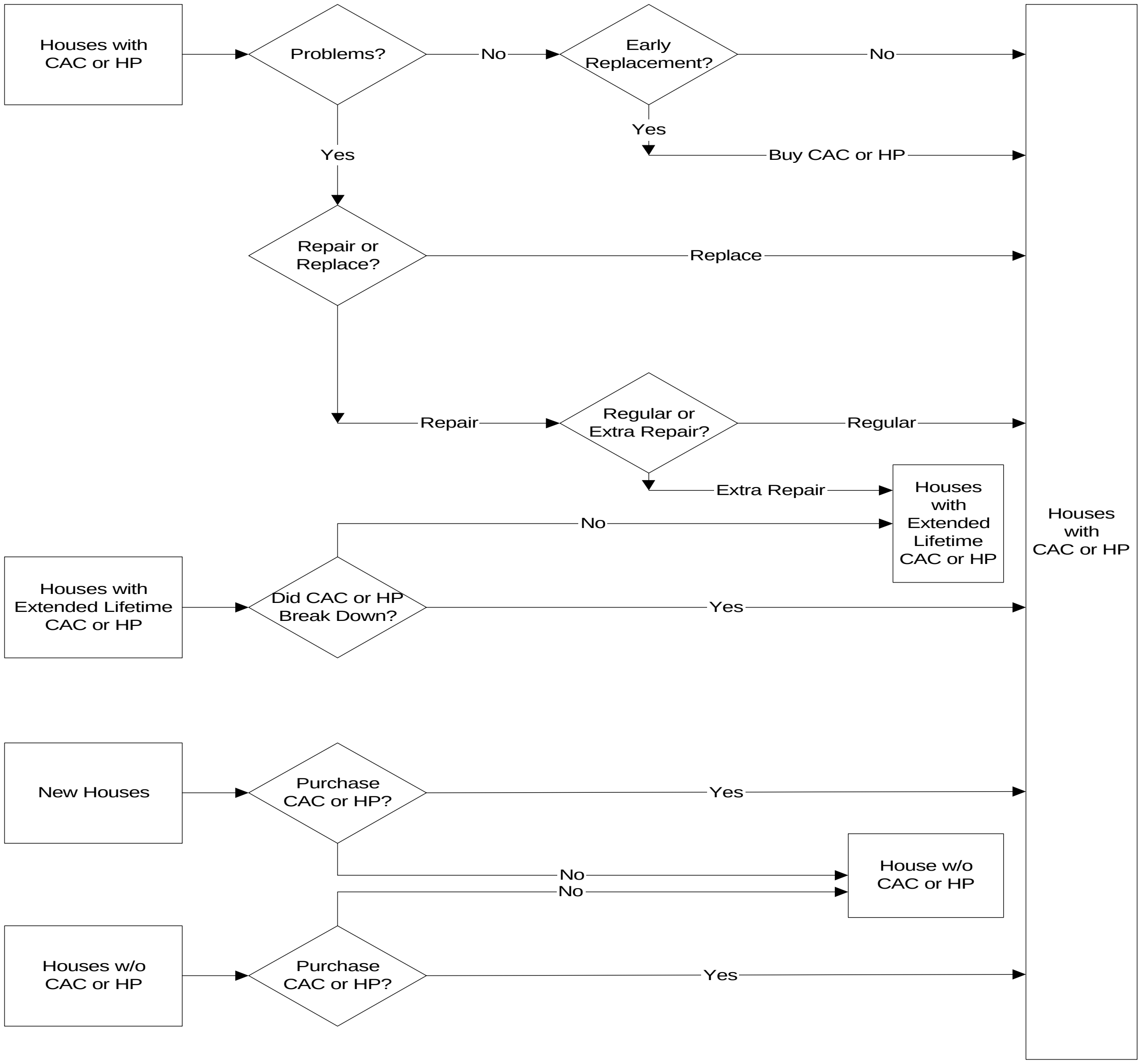

Figure 5 Flow Diagram for CAC and HP Shipments Model

Other features of the shipment model include:

Purchase price, operating cost, and income elasticities: The model includes consumer responsiveness to purchase price, operating costs, and income.

Utilization of a wide variety of data sources: The shipments model utilizes a wide range of information to make the model reflect current consumer and market characteristics. The model uses a 1990 ASHRAE technical paper on heat pump life and compressor longevity as the basis for: (1) establishing the likelihood that a system will have a problem, (2) whether the consumer will be more likely to repair or replace a system, and (3) whether or not an extra repair will be made to extend the life of the system. Data from the Air-Conditioning, Heating, and Refrigeration News are used to establish the likelihood of whether a home without a CAC or HP will purchase a system.

The purpose of these model enhancements is to provide the best estimates possible that are consistent with the recent history of CAC and HP shipments, CAC and HP market structure, and consumer preferences. Table 3 summarizes the various inputs and assumptions of the CAC and HP shipment model.

Table 3 Shipment Model Inputs and Assumptions

Parameter	Data Description
Elasticities	• Purchase price • Operating savings • Income
Market Segments	• Net new housing starts • Early replacement market • Regular replacement market • Extra repair market • Homes without an air conditioner or heat pump
Houses that drop out of air conditioner or heat pump market	Energy not accounted for.
Model type	Accounting with decision tree.
Source of Data for New Housing Starts	Census Bureau data on new housing construction.
Source of Data for Early Replacement Market	1990 ASHRAE technical paper entitled "Heat Pump Life and Compressor Longevity in Diverse Climates". In the paper, 29% of consumers in 1987 replaced their equipment for reasons other than unit failure.
Source of Data for Regular Replacement Market	1990 ASHRAE technical paper entitled "Heat Pump Life and Compressor Longevity in Diverse Climates". Survival functions for total system life and original compressor life are presented. The compressor survival function was used to establish the probability that a system has problems while the difference between the two survival functions was used to establish the probability of repair vs. replacement.
Source of Data for Extra Repair Market	1990 ASHRAE technical paper entitled "Heat Pump Life and Compressor Longevity in Diverse Climates". Total system survival function was used to establish the probability of extended or extra repair.
Source of Data for Homes without a CAC or HP	March 29, 1993 issue of the *Air-Conditioning, Heating and Refrigeration News*. In 1992, 14% of CAC and HP shipment went to non-owner households.
Source of Elasticities	*Purchase Price, Operating cost, and Income elasticities* – from *The ORNL Engineering-Economic Model of Residential Energy Use,* Oak Ridge National Laboratory, 1978.
Source of Household Income	EIA, 1999 Annual Energy Outlook.
Electricity Prices	Marginal electricity prices.
Operating cost (or savings)	Based average operating expenses from life-cycle cost analysis.

Results

The impact of each standard level on the National Energy Savings (NES) and the Net Present Value (NPV) were determined. Two sets of results were generated; one set based on the ARI manufacturer cost multipliers and the other set based on the manufacturer cost multipliers developed through reverse engineering.

Shipment forecasts had to be generated before calculating the NES and NPV results since shipments have a direct effect on the national energy savings. Changes in the shipments impact the base case as well as the standards case results. Shipments forecasts were determined for central air conditioners as a whole and heat pumps as a whole. That is, individual forecasts were not conducted for split and single package systems. Shipments forecasts were first generated in the shipments spreadsheet models, then imported into the NES models, and finally, partitioned into split and single package shipments in the NES spreadsheet models.

National Energy Savings and Net Present Values

National energy savings (NES) are the aggregate energy savings due to a higher energy efficiency standard. In other words, the difference in the energy needed for space-cooling (and space-heating in the case of heat pumps) before and after a higher efficiency standard takes effect. To estimate the energy savings through the year 2030 due to revised standards, the energy consumption of central air conditioners and heat pumps under the base case is compared to the energy consumption of central air conditioners and heat pumps complying with the standard. In other words, the NES spreadsheet determines the energy used under a base case scenario and under a standards case scenario. It then subtracts one from the other to determine energy savings. The NES spreadsheet counts a decrease in shipments as energy savings.

The national net present value (NPV), is a measure of the net economic savings to consumers. This is simply the monetary benefit of the energy savings minus the aggregate increase in cost for central air conditioners or heat pumps after a standard takes effect. When the net present value is positive, it can be referred to as a net present benefit. In determining the NPV, the energy and first costs are based on the shipments under the standard case.

Because ARI submitted manufacturer cost data for only five standard levels, NES and NPV impacts for only five standard levels were determined for both the ARI and reverse engineering cost data sets. The five standard levels analyzed for central air conditioners were: 11 SEER, 12 SEER, 13 SEER, 14 SEER, and 15 SEER. For heat pumps, the five standard levels analyzed were: 11 SEER/7.1 HSPF, 12 SEER/7.4 HSPF, 13 SEER/7.7 HSPF, 14 SEER/8.0 HSPF, and 15 SEER/8.2 HSPF. It should be noted that the manufacturer cost data developed for split systems through the reverse engineering analysis included two more standard levels for air conditioners (16 and 17 SEER) and one more standard level for heat pumps (16 SEER/8.4 HSPF). For package systems, cost data developed through the reverse engineering process were determined for only two standard levels for air conditioners (12 and 13 SEER) and one standard level for heat pumps (12 SEER/7.4 HSPF). In order to generate the reverse engineering-based shipments forecasts for standard levels for which data were not provided, package system cost data were either determined through interpolation (as in the case of the11 SEER standard level) or by using the same percentage increase in equipment price as found in split systems.

Both NES and NPV impacts (cumulative savings from the year 2006 to 2030) were calculated in two steps:

- First, in the shipments-model spreadsheet, shipments were forecasted before and after a new standard took effect and,

- Second, the shipments were then input to the National Energy Savings (NES) spreadsheet and energy savings and national economic impacts were calculated (net present value of the higher standards).

Tables 4 and 5 and Figures 6 through 9 show the cumulative NES and NPV impacts for split systems and package systems, respectively, from 2006 to 2030.

Table 4 Split System Air Conditioners and Heat Pumps: Cumulative NES and NPV impacts from 2006 to 2030

	Split Air Conditioners				**Split Heat Pumps**			
	ARI		**Rev Eng**		**ARI**		**Rev Eng**	
Efficiency	NES	NPV	NES	NPV	NES	NPV	NES	NPV
SEER / HSPF	*Quads*	*billion*	*Quads*	*billion*	*Quads*	*billion*	*Quads*	*billion*
Base Case[1]	24.33	-	24.32	-	27.76	-	27.75	-
11 / 7.1	0.68	-0.29	0.66	0.04	0.06	0.07	0.03	0.06
12 / 7.4	2.46	-2.83	2.40	-0.16	1.19	-0.43	1.07	0.61
13 / 7.7	4.08	-7.66	3.94	-1.97	2.73	-1.27	2.68	-1.15
14 / 8.0	5.49	-15.80	5.31	-8.54	4.05	-2.32	4.19	-3.85
15 8.2	6.65	-22.16	6.42	-12.27	5.50	-7.59	5.28	-5.64

[1] Values for Base Case are the cumulative national energy consumption from 2006 to 2030.

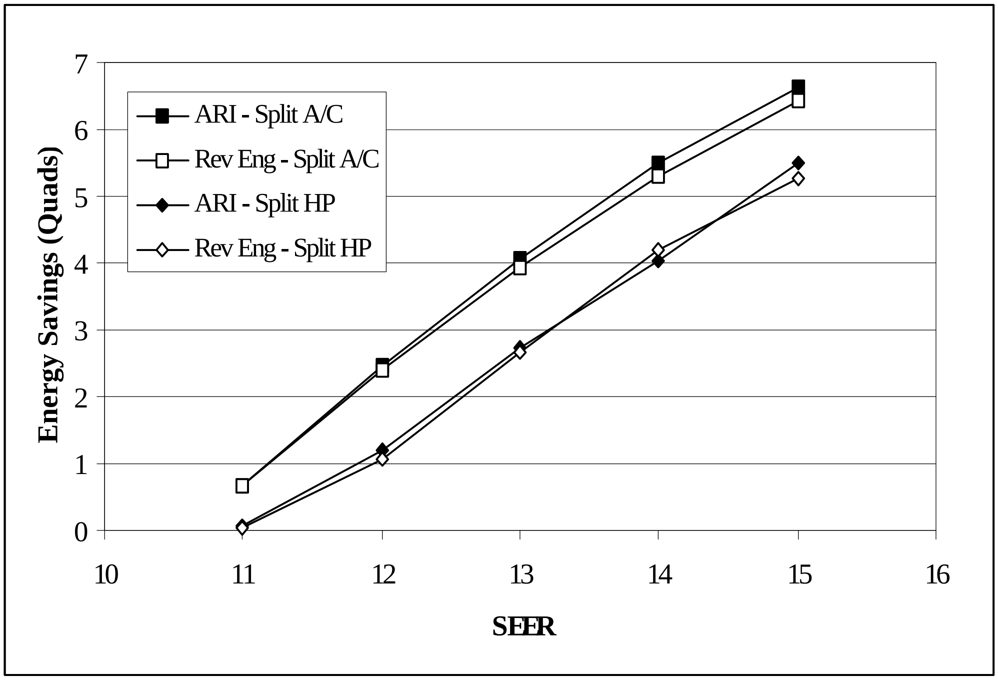

Figure 6 Split A/C and HP: Cumulative NES from 2006 to 2030

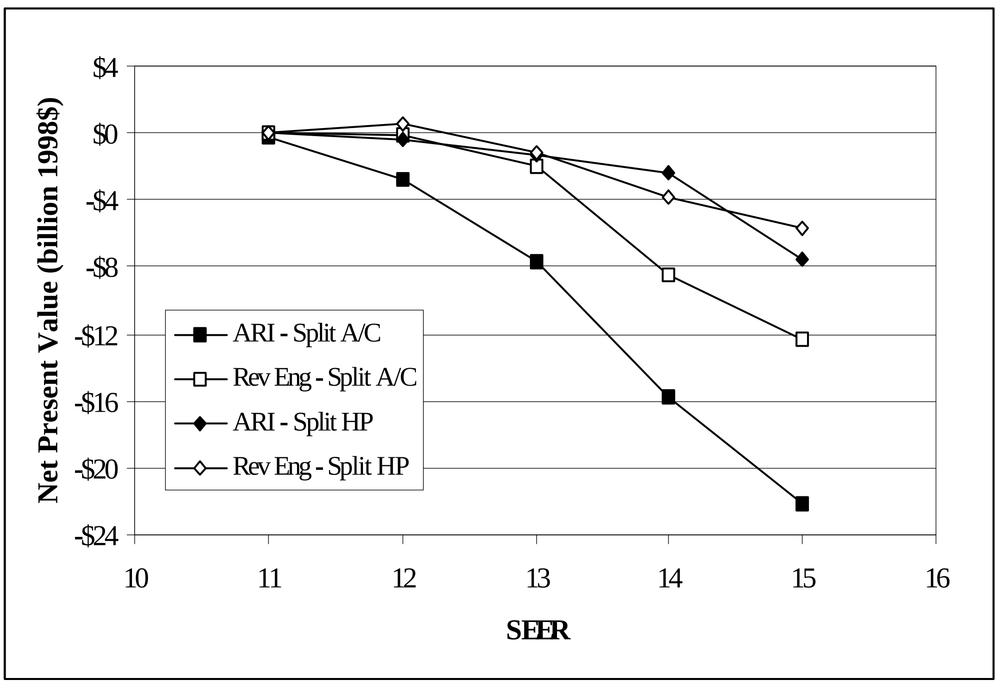

Figure 7 Split A/C and HP: Cumulative NPV from 2006 to 2030

Table 5 Single Package Air Conditioner and Heat Pumps: Cumulative NES and NPV impacts from 2006 to 2030

	Package Air Conditioners				Package Heat Pumps			
	ARI		**Rev Eng**		**ARI**		**Rev Eng**	
Efficiency	NES	NPV	NES	NPV	NES	NPV	NES	NPV
SEER / HSPF	*Quads*	*billion*	*Quads*	*billion*	*Quads*	*billion*	*Quads*	*billion*
Base Case[1]	3.83	-	3.83	-	4.66	-	4.66	-
11 / 7.1	0.11	-0.21	-	-	0.01	0.00	-	-
12 / 7.4	0.39	-0.36	0.38	0.21	0.20	-0.06	0.18	0.12
13 / 7.7	0.64	-1.96	0.62	-1.04	0.46	-0.51	-	-
14 / 8.0	0.86	-2.86	-	-	0.68	-0.52	-	-
15 / 8.2	1.04	-4.32	-	-	0.92	-1.17	-	-

[1] Values for Base Case are the cumulative national energy consumption from 2006 to 2030.

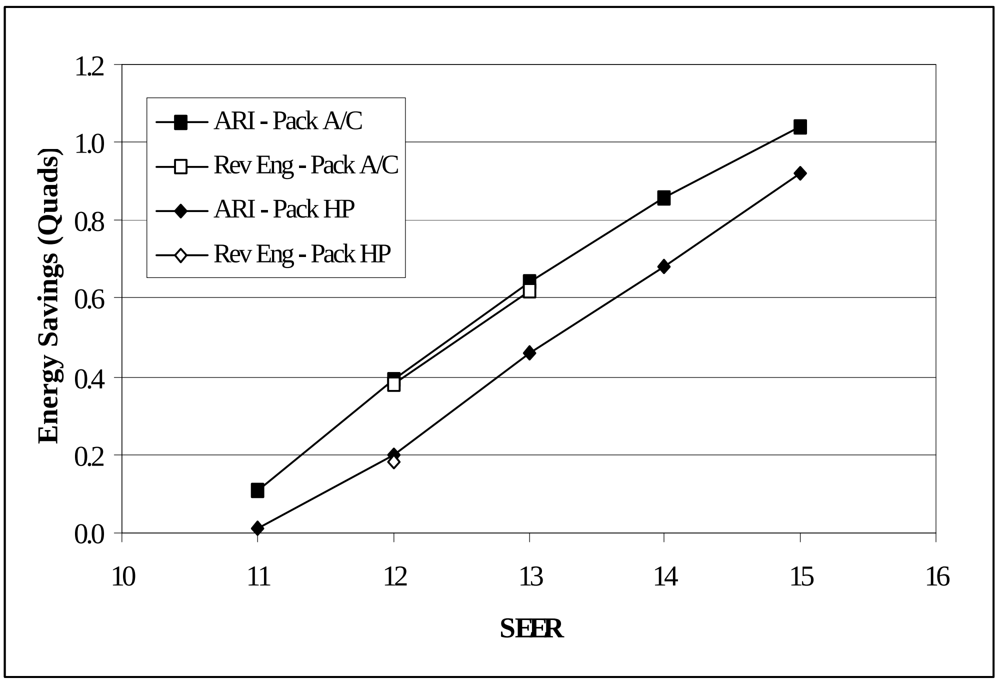

Figure 8 Package A/C and HP: Cumulative NES from 2006 to 2030

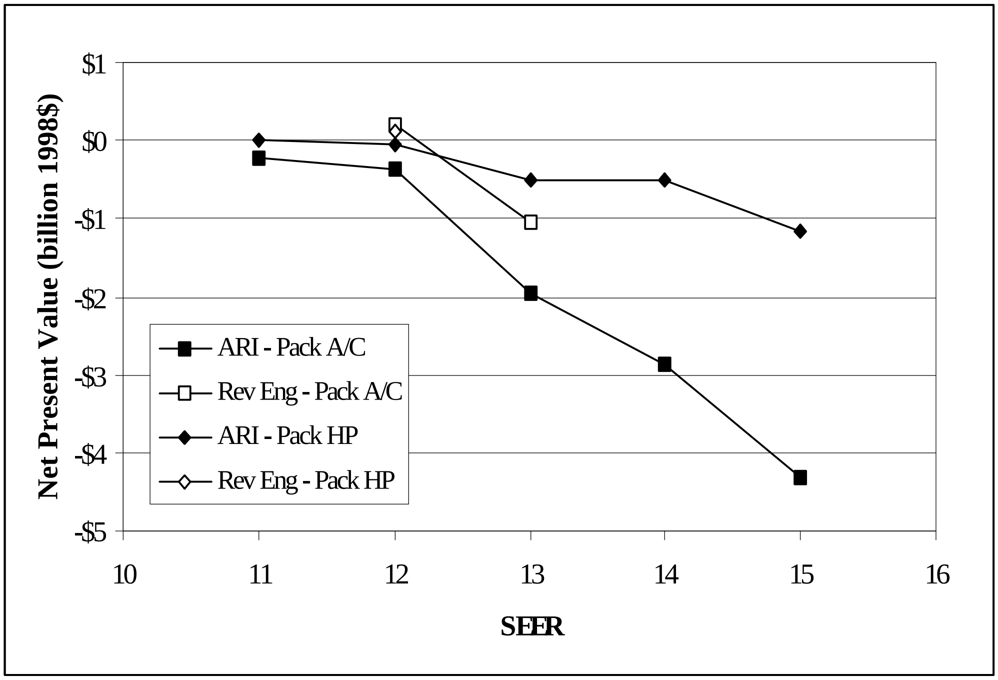

Figure 9 Package A/C and HP: Cumulative NPV from 2006 to 2030

Shipments

Figures 10 through 13 below show forecasted central air conditioner and heat pump shipments to the year 2030 for standard levels from 11 SEER through 15 SEER and the base case. Because shipments are dependent on equipment price, two sets of shipments forecasts are shown; one based on the ARI cost data and the other on the reverse engineering cost data. Historical data points are also provided to show how closely the shipments models agree with historical data.

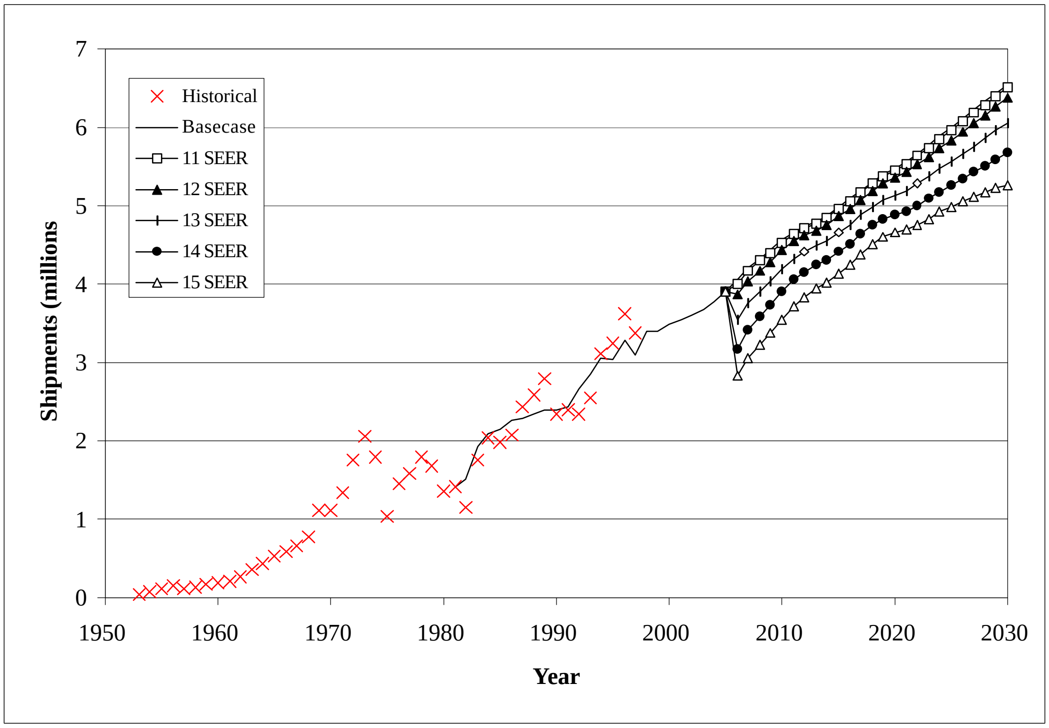

Figure 11 Central Air Conditioner Shipments Forecasts based on ARI costs

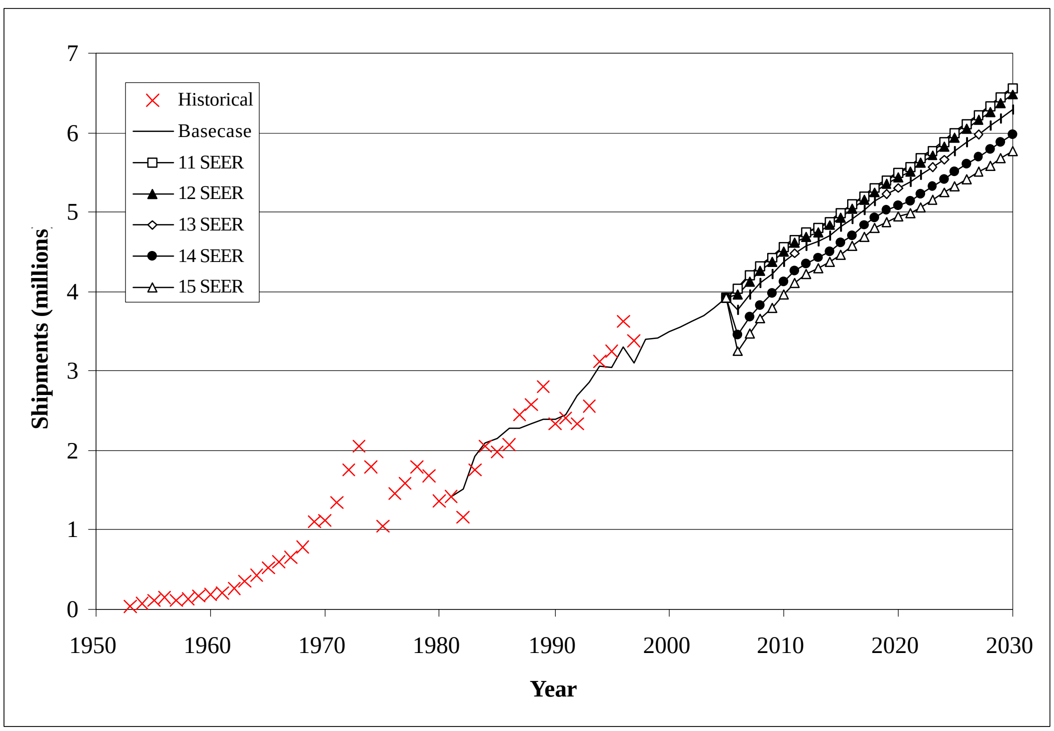

Figure 12 Central Air Conditioner Shipments Forecasts based on Reverse Engineering costs

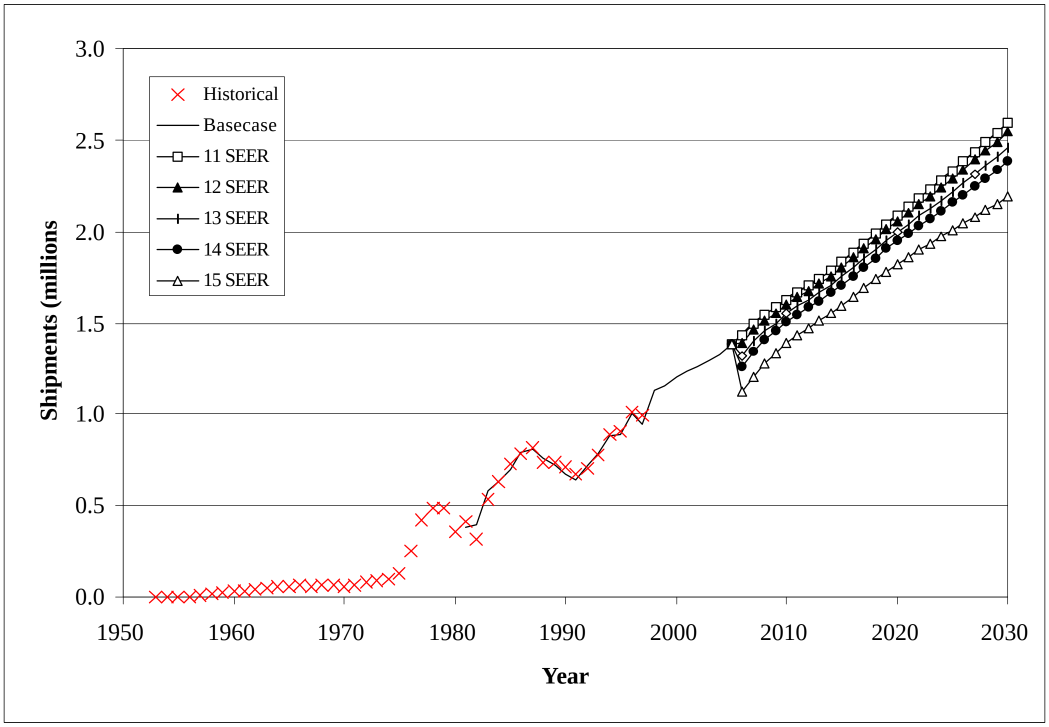

Figure 13 Heat Pump Shipments Forecasts based on ARI costs

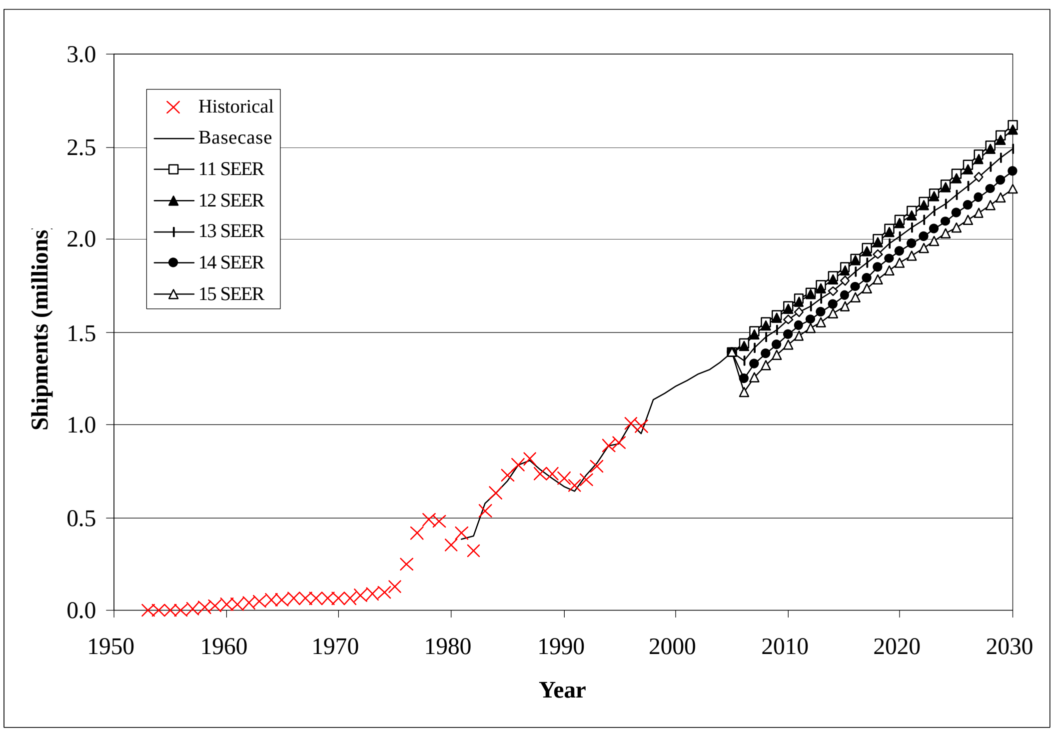

Figure 14 Heat Pump Shipments Forecasts based on Reverse Engineering Costs